CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-183
CAMP ROCK, EMERSON, GALWAY LAKE,
HOMESTEAD VALLEY (north end),
and associated faults,
San Bernardino County
by
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INTRODUCTION

As required by law, CDMG evaluates faults for potential surface rupture hazard (Hart, 1985, p. 2,5,6). The Camp Rock fault, Emerson fault, Galway Lake fault, Homestead Valley fault (north end), and several associated faults in the south central Mojave Desert, have been examined as part of this Fault Evaluation Program. Portions of these faults have been mapped by CDMG staff and by other workers (Dibblee, 1964a, 1964b, 1967a, 1967b, 1967c, 1970; Hill and Beeby, 1977; Hawkins, 1976; Morton and others, 1980; Shlemon, 1980; Dokka, 1983; Riley and Moyle (1960); Gardner, 1940), some of whom provide evidence of fault rupture during the very late Pleistocene and Holocene. Historic surface rupture is documented for the Galway Lake fault (Beeby and Hill, 1976) and the south end of the Homestead Valley fault (Hill and others, 1980). Because of these and other available reports, and air photo evidence and field observations that are described below, several of these fault traces are considered to be "sufficiently active and well-defined" faults and are recommended for zoning under the Alquist-Priolo Special Studies Zones Act.

SUMMARY OF AVAILABLE DATA

Camp Rock and Emerson faults

The Camp Rock and Emerson faults are northwest-trending, en echelon faults that extend from a few miles south of Emerson Lake to the vicinity of Daggett. Figure 1 (from Jennings, 1975) shows the Camp Rock and Emerson faults in relation to other faults in the region. Figure 2 shows the 15' and 7.5' quadrangles traversed by these faults.

The best-available geologic maps of the Camp Rock and Emerson faults are those of Dibblee (1964a, 1964b, 1967a, 1967c, 1970), who named the faults (see Figure 3). Reconnaissance mapping by Riley and Moyle (1960) shows the fault segment of the Emerson fault west of Emerson Lake. Their fault mapping is in general agreement with Dibblee's and is not shown in Figure 3. Small-scale reconnaissance mapping by Gardner (1940) shows the Camp Rock fault and the north end of the Emerson fault; his fault traces are not shown on Figure 3. Hawkins (1976) mapped a short segment of the north end of the Camp Rock fault in detail (see below, and Figure 4A).

As mapped by Dibblee, the Camp Rock fault has a length of 37.5 km (23.5 miles), and the main trace of the Emerson fault has a length of 45 km (28 miles). A 9 km-long graben or pull-apart basin is located where the southeast end of the Camp Rock fault and the northwest end of the Emerson fault overlap in an en echelon pattern (see Figure 3). Several short, subparallel faults branch off of the two main faults. Three important, southeast-trending branch faults (the Homestead Valley fault, and Faults "A" and "B") splay off of the Emerson fault west of Emerson Lake. Jennings (1975) and Rogers (1967) show a concealed northern extension of the Camp Rock fault near Daggett (see Figure 1). The extension is based on unpublished geophysical data in the files of CDMG's Regional Mapping Program.

Dibblee shows the Camp Rock fault to be vertical or near-vertical in cross section, and to have both right-lateral and vertical displacement (southwest side down) in the Ord Mountains and Rodman Mountains 15' quadrangles. The Emerson fault also is vertical in cross section, and has both right-lateral and vertical displacement (northeast side down) in the graben area (see Figure 3). Both faults offset Mesozoic bedrock and older (Pleistocene) alluvium, and are shown locally to offset and be concealed by younger alluvium (Holocene, or Holocene and very late Pleistocene, undifferentiated).

Hawkins (1976) mapped the geology along the central segment of the Camp Rock fault in detail (see Figure 4A). He shows several Tertiary units along the fault that have been displaced approximately 2 km, and notes that several drainages that cross the fault are deflected approximately 100 meters (p. 39-41). Although Hawkins states (p. vii) that he found no evidence of Holocene faulting, he estimates the age of unfaulted young alluvium to be 2,000 to 11,000 years B.P. (p. 56), and he calculates a slip rate of 1.0 cm/year for the last 11,000 years for the deflected drainages mentioned above (p. 41).

The total amount of displacement along the Camp Rock and Emerson faults is debatable. In the Ord Mountains quadrangle, Dibblee shows the Camp Rock fault to have caused 0.95 km (0.6 mile) of apparent right-lateral displacement of a Mesozoic quartz diorite body at Kane Wash. In the Rodman Mountains quadrangle, he shows 0.75 km (0.47 mile) apparent displacement of two deposits of older (Pleistocene) alluvium along the Camp Rock fault west of the Camp Rock mine, not the 1.2 km displacement claimed by Hawkins (1976, p.37). Dibblee also shows 0.33 km (0.19 mile) of right-lateral displacement of older alluvium along the Emerson fault west of Galway Lake (see Figure 3). He does not discuss fault displacements in his texts. Garfunkel (1974) hypothesizes a right-lateral displacement of 10 km along the Camp Rock fault, based on offset units shown by Roger's (1967) regional geologic map (scale 1:250,000). Miller (1980) disputes this estimate as being too high, and cites as evidence offset units shown on Dibblee's (1967c) more detailed geologic map (scale 1:62,500). However, Miller's estimate of 3.75 km requires that the offset bedrock deposits, which are situated at the graben or pull-apart basin between the Camp Rock and Emerson faults, either be laterally displaced along an inferred southeast extension of the Camp Rock fault, or displaced along the northwest end of the Emerson fault, or both. Dokka (1983, p. 307) claims that Miller and Carr's (1978) mapping along the Camp Rock fault shows several distinctive metasedimentary units that have been laterally displaced 3-5 km. Miller and Carr do not discuss displacements of these units; on their map, the outcrops of the distinctive units are separated by a deposit of Quaternary alluvium 2.5 to 3.7 km wide.

Bull (1978) includes a reconnaissance appraisal of Quaternary tectonic activity along the Camp Rock, Emerson, and other faults. He uses five differential equations, which interrelate uplift, erosion, and deposition along streams that cross mountain fronts, to divide major mountain ranges along the fault into one of three classes of terrain. According to Bull (1978, p. 33), "Class 1 ['active'] fronts occur in highly active tectonic settings that are generally characterized by active folding and/or faulting during the Holocene as well as the Pleistocene. Class 2 ['slightly active'] faulted mountain fronts generally have ruptured Pleistocene, but not Holocene, geomorphic surfaces. *** Class 3 ['inactive'] mountain fronts, by definition, have been tectonically inactive during the Quaternary." Of the ten mountain fronts along the Camp Rock and Emerson faults that were analyzed by Bull (p. 184), four are classified as "active", four are classified as "slightly active", and two are classified as "inactive" (see Figure 3). Individual segments of the faults are classified as "active", "slightly active", or "inactive" (Bull, 1978, p. 73-74). No detailed evidence of Holocene rupture was reported by Bull for any of the faults examined in this FER.

Morton and others (1980) used black-and-white, low-sun-angle air photos to produce their photoreconnaissance map of fault-related features along the Camp Rock, Emerson, and other faults (see Figures 4A, 4B, and 4C). Their annotated strip map shows alignments of scarps and tonals in younger and older alluvium, and alignments of saddles, linear trenches and drainages, closed depressions, and other features in bedrock along the general trend of the fault as mapped by Dibblee (see above). However, they did not field-check the geomorphic features, nor do they discuss recency of faulting. Their data are plotted at scales of 1:24,000 and 1:62,500 and comprise the single most-important source of information on recently-active traces of the Camp Rock and Emerson faults. [Data from the 1:62,500-scale maps have been replotted on 1:24,000-scale maps; see Figures 4B and 4C]. Most of the fault-related features shown by Morton and others were verified by photo-inspection and field-inspection during this study (see Figures 4A, 4B, 4C, and p. 5-7, below). Annotations such as "Sharply defined youthful looking scarp" suggest that the faults have been active in very late Pleistocene and Holocene time.

Shlemon (1980) conducted a study of recency of faulting, including trenching, along the Camp Rock and Emerson faults and also along the nearby Galway Lake fault (see below). The trench locations shown on Figures 4A, 4B, and 4C are approximate at best since his trench location map is missing from CDMG's copy of his report. The locations shown are from photographs of 15' topographic maps; the photos were loaned to CDMG by Shlemon. The following summary of the results of his investigation, and his conclusions, are from p. 6 and 7 of his report.

1. "The Camp Rock and Emerson Faults, presently mapped as single 40 to 60 km-long tectonic features on small scale maps (1:250,000), in reality consist of discrete, subparallel segments. Most segments are less than 10 km long; some are range-bounding, others trend into bedrock or into Holocene basin alluvium.

2. "Probable late Quaternary displacement on some segments is indicated by (a) proximity of historical seismicity; and (b) geomorphic expression, mainly linearity of mountain fronts.

3. "Trenches across the Emerson Fault encounter gouge and shear zones, but no bedrock steps; and a possible fracture, but no surface displacement of overlying sediments at least 80,000 to 125,000 years old; and no offset of fan sediments estimated [to be] 20,000 to 30,000 years old.

4. "Trenches across the Camp Rock Fault reveal no gouge zones, bedrock steps or other features indicative of large scale displacement. Possibly one metre of vertical displacement may affect intermediate-level fan surfaces at least 80,000 to 125,000, but more likely greater than about 200,000 years old. An early Holocene-late Pleistocene (ca. 8,000 - 12,000 years BP) fan surface is not offset. [This fan and trench appear to be located at the southeast end of Dibblee's Camp Rock fault trace.]

5. "Historical seismicity suggests that segments of the Emerson and Camp Rock faults south of the LVGS site are active (Holocene). But displacement along those segments within the site area is probably pre-Holocene in age. Most movements on the Emerson, Camp Rock and nearby Galway Lake Faults were probably less than a few cm per event; and thus inferentially engendered by M= 5.0 - 5.5 earthquakes, comparable to the 1975 temblor [on the Galway Lake fault]."

Galway Lake fault

A short segment of the Galway Lake fault is shown by Gardner (1940) on his small-scale reconnaissance map, but was not verified by either Riley and Moyle (1960) or Dibblee (1966, 1967a). Morton and others (1980) show the location of the existing scarps, which they identified on their air photos 1 or 2 weeks prior to the earthquakes (D.M. Morton, pers. comm., 1986). The fault was mapped in detail and named by CDMG geologists following the 5.2 magnitude earthquake of 31 May 1975 (Beeby and Hill, 1975; Hill and Beeby, 1977), and is shown on Figures 1, 3, and 4C.

Surface rupture from the earthquake extended for a length of 6.8 km, trending N.25°W to due north. Field observations and aftershock data indicate that the fault is vertical. Sense of offset is right-lateral, with maximum displacement of 1.5 cm. No surface connection with the nearby Emerson fault was found (Hill and Beeby, 1977, p. 1378-1379).

Shlemon (1980, p. 60) describes two trenches excavated across the trace of the 1975 earthquake rupture. Trench T-9, on the Galway Lake playa, exposed some small cracks, but may not have been positioned on the fault. Trench T-10, south of the lake playa*, exposed a 4 meter-wide shear zone, with the 1975 fracture extending to the surface (see Figure 7, this report). Shlemon summarizes his data and conclusions as follows:

> "The stratigraphic relationship of fractures and soil horizons within and adjacent to the Galway Lake Fault Zone indicate that there have been many movements with Quaternary time, and probably several during the Holocene. Faulting has been confined to the same zone for perhaps tens of thousands of years; and the displacement during each event was probably comparable to that generated by the magnitured 5.2 earthquake in 1975."

*The exact location of Trench T-10 is uncertain, as the trench location map is missing from CDMG's copy of this report, the trench's location was not shown on any photo, and the written description of the trench location is vague.

Homestead Valley fault

The Homestead Valley fault was first mapped by Dibblee (1964a, 1967a, 1967c), who shows the unnamed, southeast-trending splay of the Emerson fault to have an overall length of 27 km (17 miles) (see Figure 1). In the Rodman Mountains quadrangle, Dibblee (1964a) shows the fault as separating Mesozoic bedrock and Pleistocene alluvium (see Figure 3). Further to the southeast, Dibblee (1967a, 1967c) shows the fault separating Mesozoic bedrock and young alluvium (Holocene and very late Plesitocene, undifferentiated), and locally to offset and be concealed by younger alluvium and windblown sand. Sense of displacement is right-lateral strike-slip. A series of moderate-magnitude earthquakes on 15 March 1979 resulted in surface rupture in young alluvium along the Homestead Valley fault in the Landers 7.5' quadrangle (Hill and others, 1980). Additional data for the Homestead Valley fault is summarized by Manson (1986), who recommended zoning the entire length of the fault in the Old Woman Springs and Emerson Lake 15' quadrangles.

Faults "A" and "B"

Faults "A" and "B" are unnamed, southeast-trending splays of the Emerson fault that are shown by Dibblee (1967a, 1967c) and by Riley and Moyle (1960). Both faults are parallel to the Homestead Valley fault, which lies a few kilometers west of Fault "A" (see Figure 3, this report).

Fault "A" has an overall length of 12 km (7.3 miles). Displacement along Fault "A" is shown by Dibblee (1967a) to be both right-lateral and vertical (west side up). Total displacement along Fault "A" is not known. The fault truncates Mesozoic bedrock, and locally is shown to offset and be concealed by young alluvium (Holocene and very late Pleistocene). Riley and Moyle (1960) are in general agreement with Dibblee as to the fault's location, but they show only a single trace. A short segment of Fault "A" is mapped by Morton and others (1980).

Fault "B" has a length of 5.3 km (3.3 miles). Sense of displacement is not indicated by Dibblee (1967a) or by Riley and Moyle (1960). The fault offsets Mesozoic bedrock and separates bedrock and young alluvium. The southeast end of the fault is concealed by young alluvium. Fault "B" is not shown by Morton and others (1980).

Fault "C"

Fault "C" (Figures 3 and 4A) is a northern extension of Bryant's (1986) Fault "E" in the Yucca Valley North 7.5' quadrangle. This fault is mapped by Dibblee (1967a, 1968), and in part by Morton and others (1980). Bader and Moyle (1960) mapped the fault segment south of the Marine base. Total length of Fault "C" is 10 km (6.4 miles), with 7 km (4.5 miles) in the Emerson Lake 15' quadrangle. Sense of displacement and amount of offset are not given, although Dibblee shows Fault "C" as separating Pleistocene-age older alluvium on the east from young alluvium (very late Pleistocene and Holocene) on the west. The fault is shown to be concealed locally by young alluvium. Fault "C" appears to be a left-step continuation of the Copper Mountain fault: the Copper Mountain fault lies on the east flank of Sand Hill, and Fault "C" lies on the west flank (see Figure 3). Bryant noted local geomorphic features permissive of recent faulting along the southern segment of Fault "C", but felt that they may be erosional in origin. He recommended against zoning this fault because the fault is neither sufficiently active nor well-defined in his study area.

Fault "D"

Fault "D" is a short (4.7 km; 3.0 miles), northwest-trending fault in Pleistocene alluvium north of Fault "C". As shown by Dibblee (1967a; see Figure 3) the fault locally is concealed by young alluvium (very late Pleistocene and Holocene), but elsewhere separates young alluvium and colluvium from older alluvium. Fault "D" may be a southeastern surface extension of the Emerson fault, as it lies on trend with and 3 km southeast of the Emerson fault. However, deformation of the local surficial units by folding as well as faulting is suggested by the existence of Hill 2794, which Dibblee (1967a) shows as a doubly-plunging anticline in Pleistocene alluvium, between the two faults (see Figure 3). Some discontinuous traces are shown by Morton and others (see Figure 4A).

Copper Mountain fault (north end)

The Copper Mountain fault extends southeastward from Sand Hill, at the southern margin of the Emerson Lake 15' quadrangle, into the Joshua Tree and Twentynine Palms 15' quadrangles (see Figure 3). The north end of the fault, that segment within the Emerson Lake quadrangle, has a length of approximately 1.7 km (1.0 mile). Dibblee (1968) shows the fault to be concealed by Pleistocene alluvium along the east flank of Sand Hill. Bryant (1986) examined the 15 km-long segment of the Copper Mountain fault within the Joshua Tree and Twentynine Palms 15' quadrangles. Summarizing his air photo interpretation and field observations, Bryant notes the following data:

> "The Copper Mountain fault is a northwest-trending fault delineated by a well-defined, linear, southwest-facing escarpment in bedrock. *** The fault is generally well defined northwest of sec. 13, T1N, R7E and south of Sunfair Road and is delineated by subtle geomorphic evidence indicating Holocene down-to-the-west normal faulting. *** In addition, stream cut exposures revealed offset Holocene alluvium. Faults in the alluvial deposits varied in trend from N25°W to N50°W, and generally had southwest dips from 50° to near vertical. *** Faults mapped by Bader and Moyle (1960), Dibblee 1967b, 1968), and Morton and others (1980) were verified, in general, but significant differences in detail exist".

Based on the data cited above, Bryant recommended zoning the Copper Mountain fault for Special Studies to within 1.0 km of the south boundary of the Emerson Lake 15' quadrangle. The northernmost fault segment in the Joshua Tree quadrangle was so poorly defined that it did not meet zoning requirements.

AIR PHOTO INTERPRETATION AND FIELD OBSERVATIONS

My air photo interpretations and field observations for the Camp Rock, Emerson, Galway Lake, and associated faults, are included in Figures 4A, 4B, and 4C. Figure 4A is a photo reconnaissance map (scales 1:24,000 and 1:62,500) of young-looking fault features along the Camp Rock, Emerson, and Galway Lake faults by Morton and others (1980, sheet 3), and also includes detailed mapping by Hawkins (1976). Figures 4B and 4C (scale 1:24,000) include the data shown by Morton and others at a scale of 1:62,500. In general, the features noted by Morton and others were verified during this study, and are accurately located. However, some features shown by them were not verified.

Three sets of black-and-white air photos were available to me: U.S.B.L.M., 1978, series CA 93-77; U.S.B.L.M., 1978, series CA HD-77; and U.S.D.A., 1952, series AXL. A partial set of black-and-white air photos (American Aerial Surveys, Inc., 1973) was loaned to C.D.M.G. by Roy Shlemon. The low-sun-angle air photos used by Morton and others (1980) were not available. Field inspections of the Camp Rock, Emerson, Galway Lake, and associated faults were made on January 16, July 7 and 11, and July 22-25, 1986. William Bryant and Earl Hart, C.D.M.G., assisted in field work on January 16. Glenn Borchardt, C.D.M.G., assisted in field work on July 7 and 11. Earl Hart assisted in air photo interpretation.

Access to the southeastern segment of the Emerson fault, which is located within the Marine Corps Training Center - 29 Palms, was denied by the Corps due to the large-scale manuvers being conducted during the latter part of July. Faults "B", "C", and "D", and the Copper Mountain fault were not field-checked due to time constraints or because the fault is located on the Marine base.

<u>Camp Rock and Emerson faults</u>

The Camp Rock fault is a well-defined linear surface feature from the Camp Rock Mine area northwestward along Camp Rock Road to sec. 23, T8N, R1E, in the Mineola 7.5' quadrangle (see Figures 4A and 4B). Geomorphic evidence of the fault's location includes scarps, linear drainages and deflected drainages. Southeastward from the Camp Rock Mine area to the Bessimer Mine, the active trace is generally well-defined in bedrock but is largely concealed by young alluvium (see Figures 4B and 4C). At Location 1 (Figure 4B) the fault has formed a southwest-facing scarp in late Pleistocene alluvium estimated to be 80,000 to 230,000 years old (Borchardt, 1986), but is concealed by younger, pre-Holocene alluvium.

The northwestern half of the Emerson fault is moderately well-defined in bedrock, but locally is concealed by younger alluvium (Holocene and very late Pleistocene), and by alluvial fans and debris flows of late Pleistocene or very late Pleistocene age (Location 2, Figure 4C). At Location 3 (Figure 4C) is a northwest-trending graben in bedrock and Pleistocene alluvium. The northwest end of the graben is blocked by a large, active alluvial fan. North of the graben, geomorphic evidence of the fault's location and recency of movement is sparse, and the fault trace is largely concealed by young alluvium. West of Emerson Lake, the Emerson fault generally is defined by the northeast-facing break-in-slope with some geomorphic features locally (sidehill bench, linear drainage). From the south end of Emerson Lake, southeastward to Creole Mine Road (Figure 4A) is an alignment of several prominent, northeast facing scarps in Pleistocene alluvium of Dibblee (1967a). Several, but not all, of the scarps and troughs in young alluvium shown by Morton and others (1980) between Creole Mine Road and Hill 2794 were verified by my air photo interpretation. A broad zone of discontinuous tonals and possible scarps in Pleistocene alluvium trends south-southeastward to

Surprise Springs Road, where Dibblee (1967a) and Bryant (1986) show southern extensions of Fault "C" and the Copper Mountain fault in the adjacent quadrangles.

Galway Lake fault

The Galway Lake fault is poorly defined on the available air photos, with only an alignment of widely-separated bedrock ridges visible on the photos. Although some deflected drainages and scarps were located in the field, no evidence of the 1975 surface rupture was visible when the fault was field checked in January (see Figures 4A and 4C).

Homestead Valley Fault

The Homestead Valley fault has a complex junction with the Emerson fault. The north end of the Homestead Valley fault, in the Rodman Mountains quadrangle, is marked by a discontinuous series of bedrock scarps, locally mantled with dune sand, that extends southeastward into the Old Woman Springs and Emerson Lake 15' quadrangles. See Manson (1986) for additional data in the latter quadrangles.

Faults "A", "B", "C", and "D"

Fault "A" is moderately well-defined in bedrock (see Figure 4A). Several scarps, sidehill benches, and linear drainages suggest recent lateral movement. Locally, the fault is concealed by stabilized dune sand.

Fault "B" is poorly defined to moderately defined in bedrock in the air photos, with only a few saddles or notches in bedrock to suggest location (see Figure 4A).

Fault "C" can be followed northward from Sand Hill as an eroded, west- or northwest-facing scarp in Pleistocene alluvium (see Figure 4A). The northern segment of the fault, in sec. 1, T2N, R6E, and sec. 36, T3N R6E, is generally concealed by young alluvium. Strike-slip displacement is indicated by the linearity of the trace. Vertical displacement (east side up) along the fault is suggested by the length of the scarp, and by the incision of several moderate-size drainages across the scarp (see Figure 4A). The north end of the fault dies out slightly west of the southeast end of Fault "D", suggesting a right step-over between the fault traces.

Fault "D" is delineated on the air photos as an eroded, southwest-facing scarp in Pleistocene alluvium. The scarp is more eroded than similar scarps at Location 1 (along the Camp Rock fault) and Location 4 (along the Emerson fault, northwest of Creole Mine Road). Three closed depressions at the base of the scarp suggest recent faulting (see Figure 4A). As with Fault "C", the linear scarp suggests strike-slip faulting, while truncation of northeast-trending drainages by the back-facing scarp indicates vertical displacement (northeast side up).

Copper Mountain fault (north end)

I saw no air photo evidence of surface faulting in Pleistocene alluvium, along the northernmost segment of the Copper Mountain fault. The concealed fault shown by Dibblee (1967a, 1968) could not be traced across incised drainages in the older alluvium (see Figure 4A).

SEISMICITY

Figures 5A and 5B are en echelon segments of a map showing regional seismicity for the period 1969-1984 (Calif. Institute of Technology, 1985). Very few events are recorded for the Camp Rock fault and the north end of the Emerson fault. A large number of events are shown along the Galway Lake fault (probably related to the earthquake of 31 May 1975), along the Homestead Valley fault (which had numerous earthquakes during March-June 1979) and also along Fault "A". A large cluster of events is located near Goat Mountain, which lies west of the south end of the Emerson fault (see Kanamori and Fuis, 1976).

CONCLUSIONS

A. The Camp Rock fault is a northwest-trending, right-lateral strike-slip fault that locally has minor components of vertical displacement. Total fault length is 37.5 km (Dibblee, 1964a, 1964b, 1970). A 9 km-long graben or pull-apart basin appears to be formed by the southeast end of the Camp Rock fault and the northwest end of the Emerson fault (see below). An inferred and concealed northwestern extension of the Camp Rock fault to the Harper fault zone, shown by Rogers (1967) and Jennings (1975), is based on unpublished geophysical data in the files of CDMG. The extension is not confirmed by Dibblee (1970), and I saw no air photo evidence of surface rupture along the trend of the inferred fault.

The Camp Rock fault, as mapped by Dibblee (see Figure 3) is generally well-defined in bedrock and Pleistocene alluvium, from sec. 14, T8N, R1E, southeastward to near the Bessemer Mine. Faulted Holocene alluvium is shown by Dibblee northwest of Location 1 (Figure 4B), but Hawkins (1976) states that several deposits of "Holocene" alluvium (2,000 - 11,000 years B.P) are unfaulted. At Location 1 is a southwest-facing scarp in Pleistocene alluvium that is estimated to be 80,000 to 230,000 years old (Borchardt, 1986), while younger, pre-Holocene alluvium at the base of the scarp appears to be unfaulted. Trenches across the southeastern end of the Camp Rock fault revealed evidence of faulting, but were inconclusive as to age of fault activity (Shlemon, 1980). Estimates of total lateral displacement along the fault vary from .95 km (Manson, this report) up to 3.75 (Miller, 1980), with a discredited estimate by Garfunkel (1974) of 10 km.

B. The Emerson fault is a right-lateral, strike-slip fault which lies parallel to and southwest of the Camp Rock fault (see Figure 3). The Emerson fault terminates several other strike-slip faults, including the active Homestead Valley fault, Fault "A", and Fault "B". Fault "D", southeast of the Emerson fault, may be an extension of the Emerson fault, as it is parallel to and aligned with the latter fault. Lateral displacement of Pleistocene alluvium along the Emerson fault west of Galway Lake is at least .33 km. The fault locally is well-defined in bedrock and Pleistocene alluvium, but is often concealed beneath colluvium and young alluvial fans. Some segments are defined only by a general break-in-slope between bedrock and alluvium. Strike-slip displacement is indicated by the linearity of the fault trace and scarps, and some vertical offset is indicated by the graben near the northwest end of the fault (Locations 2 and 3). The southeast end of the fault locally offsets and is concealed by young alluvium (Holocene and very late Pleistocene).

The northern segment of the Emerson fault appears to be less active. An unfaulted fan at Location 2 is of very late Pleistocene age. Nearby trenches described by Shlemon (1980) indicate a possible cracking of overlying sediments estimated to be 80,000-125,000 years old, and that fan deposits estimated to be 20,000-30,000 years old are unfaulted.

C. The historically active Galway Lake fault (Hill and Beeby, 1977) is moderately well-defined in bedrock, but generally is concealed by young alluvium. Trenching by Shlemon (1980) indicates that several events have occurred during the Holocene. Although no surface connection of the Galway Lake and Emerson faults is known, no trenching or geophysical work to confirm this hypothesis has been attempted, and the proximity and trend of the two faults is permissive of a physical connection.

D. Fault "A" is an unnamed, southeast-trending branch of the Emerson fault that is parallel to and east of the Homestead Valley fault. Sense of displacement is right-lateral strike-slip with minor vertical offset (west side up). The fault is generally well-defined in bedrock by young-looking fault features, and is concealed locally by dune sand.

E. Fault "B" is a minor southeast-trending fault that lies east of Fault "A". Sense of displacement along the fault is not indicated by Riley and Moyle (1960) or Dibblee (1967a), and the fault is poorly defined in bedrock. The south end of Fault "B" is concealed by young alluvium (very late Pleistocene and Holocene).

F. Faults "C" and "D" are minor, en echelon faults between the north end of the Copper Mountain fault and the southeast end of the Emerson fault. Both faults are moderately well-defined surface features with west- or southwest-facing eroded scarps in Pleistocene alluvium. Right-oblique displacements along Faults "C" and "D" are indicated by the linearity of the scarps and the incision of each scarp by pre-existing drainages. The scarps are more degraded than are scarps in similar material along the Camp Rock fault (Location 1) and the Emerson fault (Location 4). However, three closed depressions are located at the base of Fault "D", suggesting recent faulting.

G. The northern end of the historically active Homestead Valley fault, in the Rodman Mountain 15' quadrangle, can be traced as a discontinuous series of northeast-facing bedrock scarps that locally are mantled with dune sand. The fault has a complex junction with the Emerson fault (see Figures 3 and 4C).

H. The Copper Mountain fault is a right-lateral strike-slip fault that extends southeastward from Sand Hill (Figure 4A). The north end of the Copper Mountain fault is shown by Dibblee (1967a) to be concealed by Pleistocene alluvium, and I saw no air photo evidence of surface faulting along this segment. Bryant (1986) recommended that zoning of the Copper Mountain fault be restricted to the better-defined central and southern segments of the fault, in the Joshua Tree and Twentynine Palms 15' quadrangles.

RECOMMENDATIONS

The zoning recommendations listed below are based on the concept of "sufficiently active and well-defined" (Hart, 1985, p. 5-6):

1. The central segment of the Camp Rock fault should be zoned for Special Studies as shown in Figures 6A and 6B. This segment is generally well-defined in bedrock, and locally is well defined in late Pleistocene alluvium. Although pre-Holocene alluvium near the Camp Rock Mine appears to be unfaulted, geomorphic evidence near the northern end of the fault (northwest of Kane Wash) suggests Holocene activity. References cited should be Morton and others (1980), and this report for location and recency. Hawkins (1976) and Dibblee (1964a, 1964b, 1970) should also be cited as substantial confirmation, although their exact traces were not used. The fault segments northwest of the S 1/2 sec. 14 in the Mineola quadrangle, and southeast of the power lines in the Iron Ridge quadrangle, should not be zoned as they are concealed or poorly defined.

2. The Emerson fault should be zoned for Special Studies as shown on Figures 6B and 6C. The fault locally is well-defined in bedrock or in Pleistocene alluvium, and also in alluvium of Holocene and very late Pleistocene age. References cited should be Morton and others (1980) and this report for location and recency. Dibblee (1964b, 1967a) should also be cited as substantial confirmation, although his specific traces were not used. The northernmost segment of the Emerson fault should not be zoned, as it is concealed or poorly defined locally.

3. The Galway Lake fault should be zoned for Special Studies as shown in Figures 6B and 6C. References cited should be Hill and Beeby (1977) for location and recency, and Morton and others (1980), Shlemon (1980), and this report for confirmation of location or recency.

4. The north end of the Homestead Valley fault should be zoned for Special Studies as shown on Figure 6C, as it is a generally well-defined surface feature in bedrock, and it is the northern end of a fault that had surface rupture in 1979. References cited should be this report for location and recency of faulting. Dibblee (1967a) should also be cited as substantial confirmation, although his specific traces were not used.

5. Fault "A" should be zoned for Special Studies as shown on Figure 6C, as it is a generally well-defined surface feature, and it has several geomorphic features in bedrock that suggest recent faulting. References cited should be Morton and others (1980) for location, and this report for location and recency. Dibblee (1967a) should also be cited as substantial confirmation, although his specific traces were not used.

6. Fault "B" should not be zoned, as it is not well defined in bedrock, and has little air photo evidence of recent faulting.

7. Faults "C" and "D" should be zoned for Special Studies as shown in Figure 6C. Although the southwest-facing scarps in Pleistocene alluvium appear to be more degraded than are other scarps in similar material (Locations 1 and 4), Faults "C" and "D" are better defined than the southeast end of the Emerson fault, or the northwest end of the Copper Mountain Fault where Bryant (1986) has recommended zoning (W.A. Bryant, p.c., 1986). Distributive faulting and folding of units in this area would result in a more subdued appearance of the fault scarps. References cited should be this report for location and recency. Dibblee (1967a) and Morton and others (1980) should be cited as substantial confirmation, although their specific traces were not used.

8. The north end of the Copper Mountain fault, within the Emerson Lake 15' quadrangle, should not be zoned because it is mapped by Dibblee (1967a) as a concealed fault, and it could not be verified on air photos as a surface feature in Pleistocene alluvium.

Michael W. Manson

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R.G. 3690

Report reviewed.
I generally agree
with the recommendations
(see pencil notes on Fig. 6
for minor modifications
in zone map).
EWH
11/10/86

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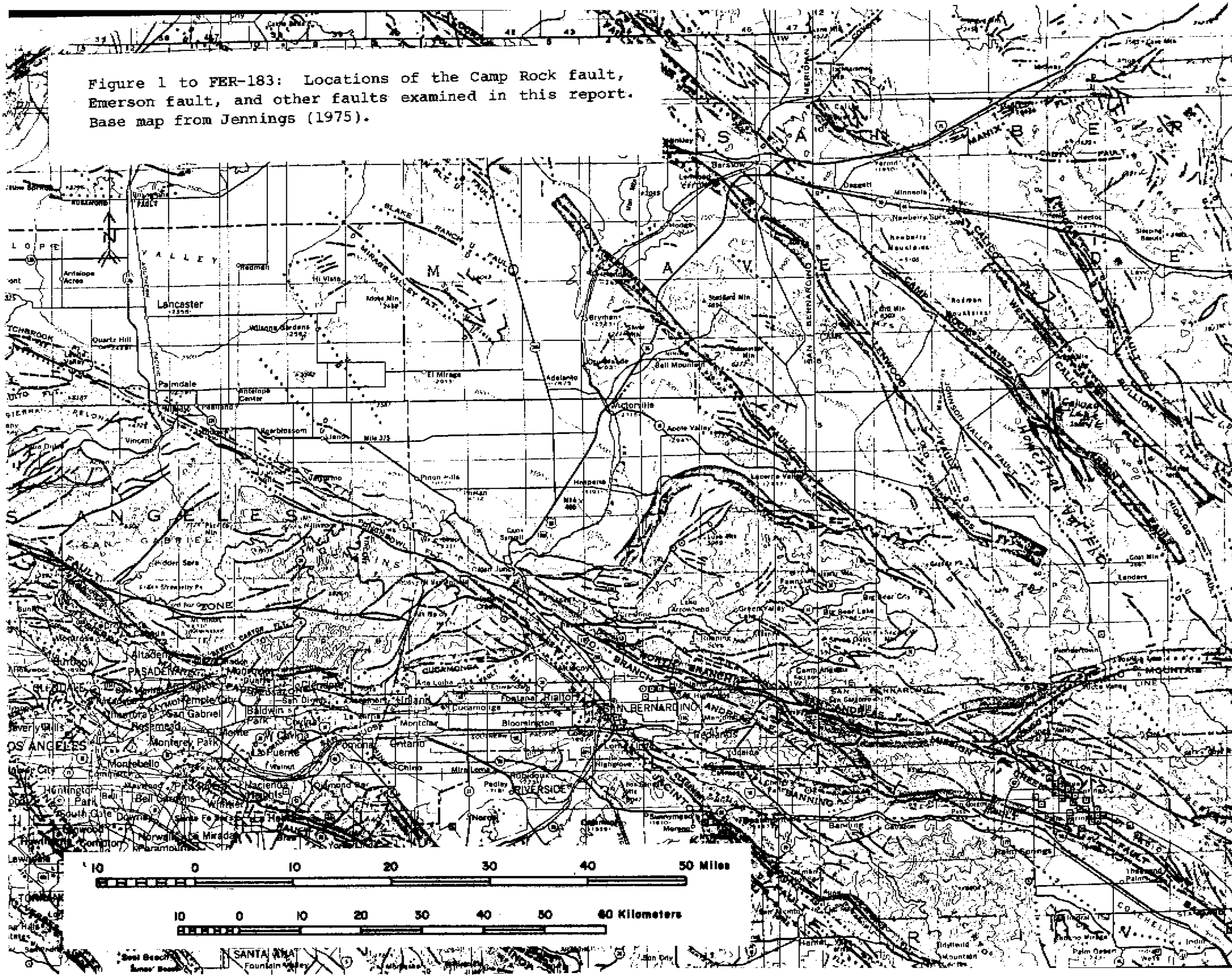


Figure 1 to FER-183: Locations of the Camp Rock fault, Emerson fault, and other faults examined in this report. Base map from Jennings (1975).

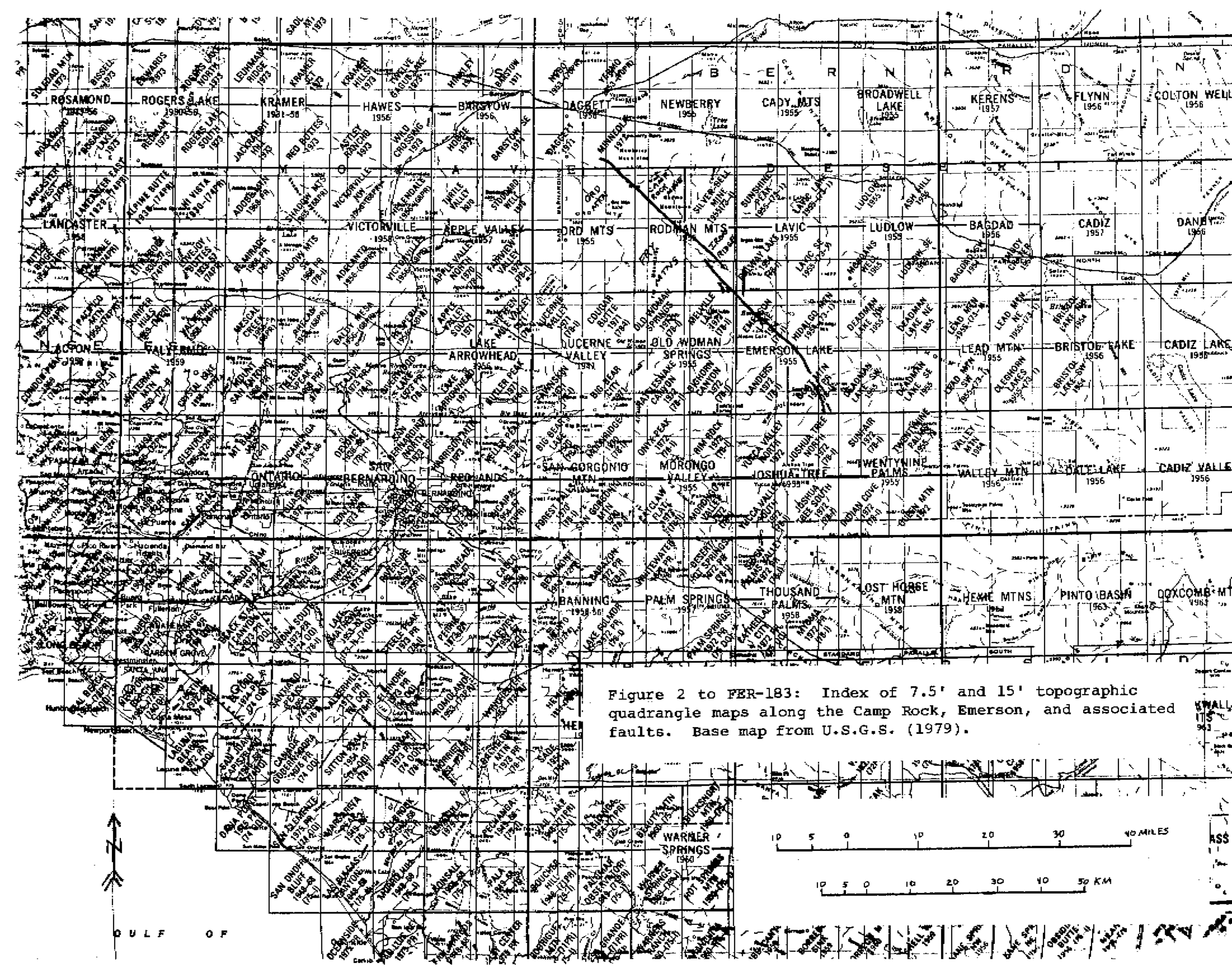


Figure 2 to FER-183: Index of 7.5' and 15' topographic quadrangle maps along the Camp Rock, Emerson, and associated faults. Base map from U.S.G.S. (1979).

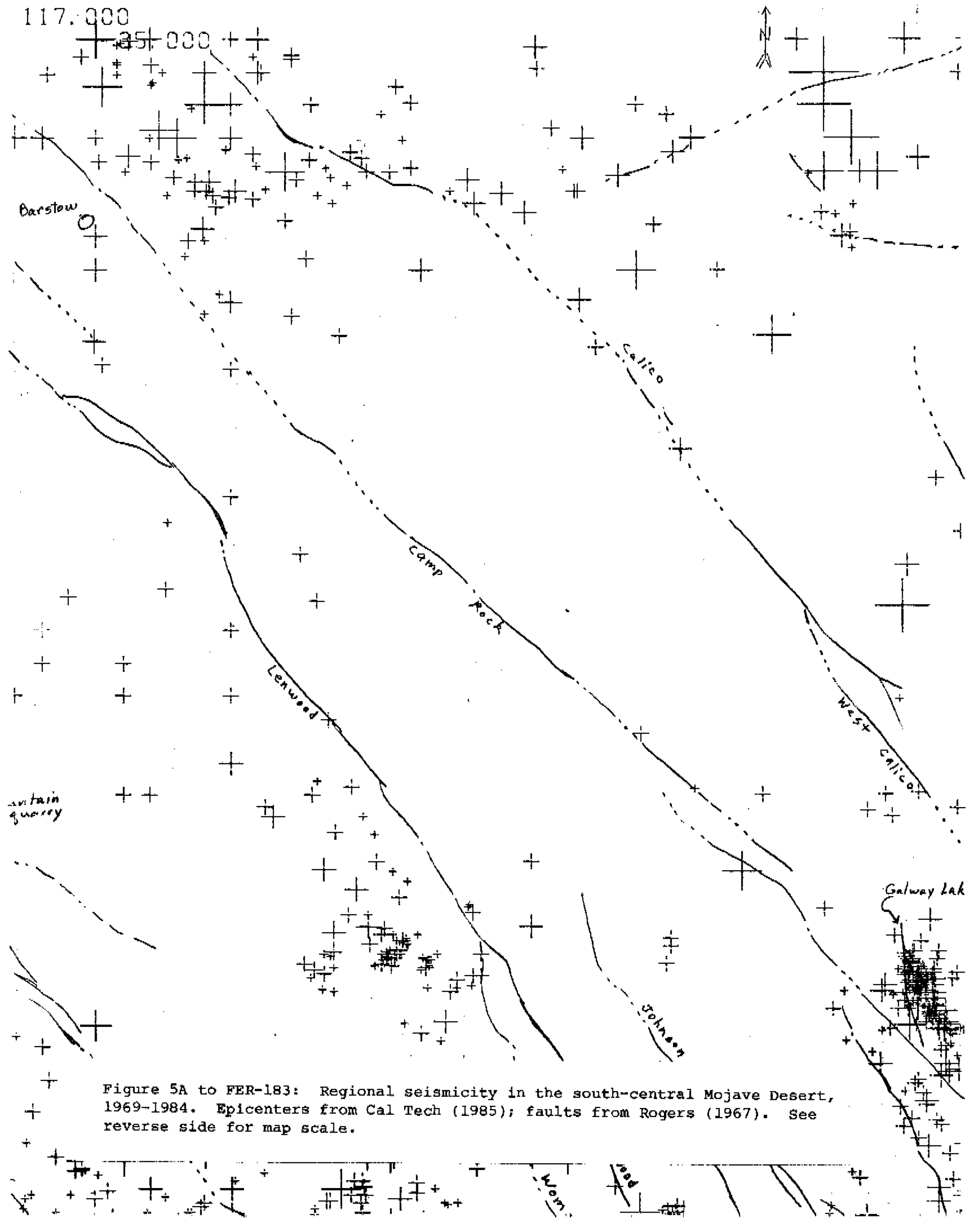
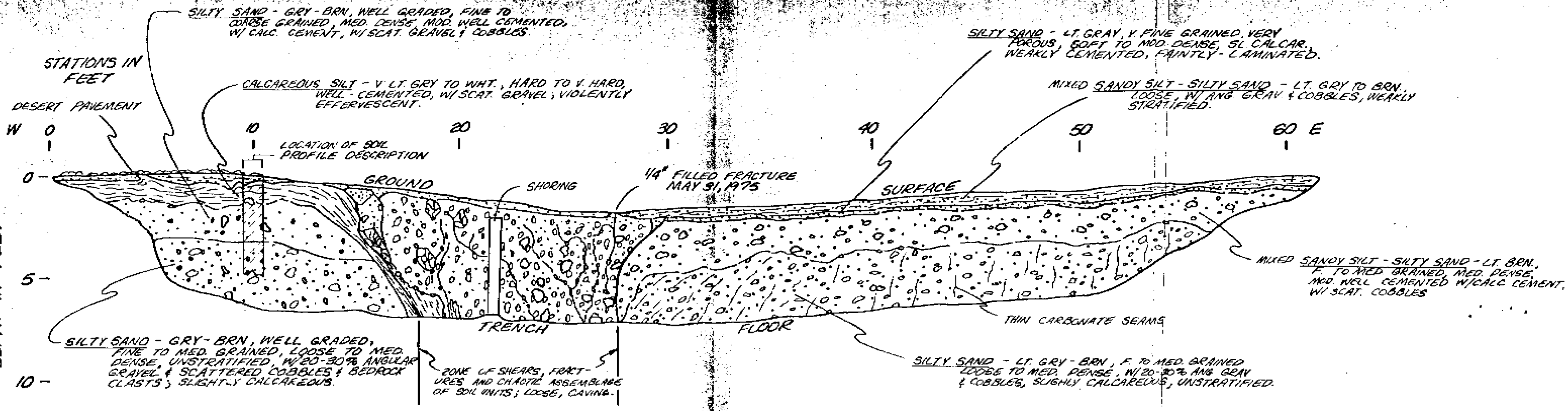


Figure 5A to FER-183: Regional seismicity in the south-central Mojave Desert, 1969-1984. Epicenters from Cal Tech (1985); faults from Rogers (1967). See reverse side for map scale.

GALWAY LAKE FAULT



TRENCH T-10 (SEC. 19, T. 5 N., R. 5 E.)

HORIZONTAL & VERTICAL SCALE 1" = 5'

VIEW TO NORTH

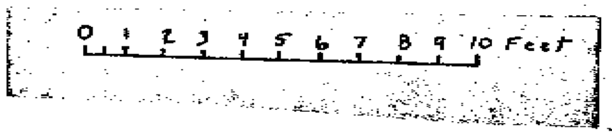


Figure 7 to FER-183:

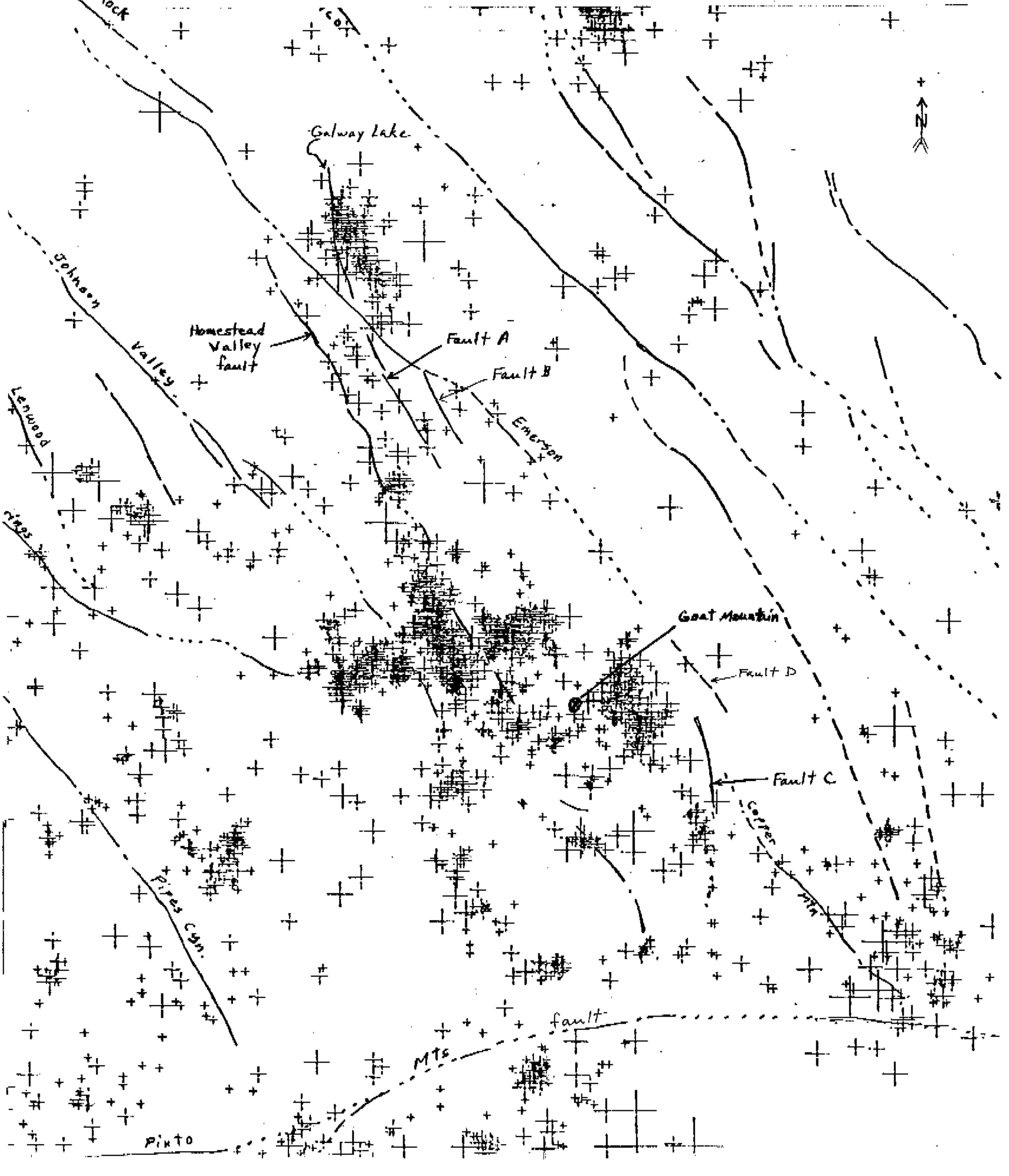
Log of Trench T-10

(from Shlemon, 1980, fig. 18).

[redacted]

12-6-79 PD

Figure 5B to FER-183: Regional seismicity in the south-central Mojave Desert, 1969-1984. Epicenters from Cal Tech (1985); faults from Rogers (1967). See reverse side for map scale.



EARTHQUAKES M1.0 OR GREATER

CIT 1969-1984 AB QUALITY ONLY

SAN BERNARDINO SHEET

TRANSVERSE MERCATOR PROJECTION

SCALE = 1/250000

MAGNITUDE

..... 1.0 TO 1.9

..... 2.0 TO 2.9

..... 3.0 TO 3.9

..... 4.0 TO 4.9

..... 5.0 TO 5.9

..... 6.0 TO 6.9